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STATISTICS OF WATER POWER EMPLOYED IN MANUFACTURING IN THE UNITED STATES.

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It may safely be said that in no country on the globe is there so large an amount of water power employed as in the United States of America. In no country are there so many large developed powers, so many large manufacturing cities which owe their existence to the proximity of available sites, so many instances of large companies developing power at great cost, and selling it to extensive manufacturing concerns like any other commodity. In the engineering problems involved in the development of large powers, as well as in the diverse questions relating to their management, this country has taken the lead. Our engineers have been called upon to advise in the construction of similar works abroad, and foreign engineers have repeatedly sought our shores to gain information on this particular subject.

The water power of the country is not the least important of its natural resources, and its value is probably not realized by most of us. According to the returns of the Tenth Census, there were in use for manufacturing in the United States, in 1880, 55,404 water wheels, using a total

power of 1,225,379 horse-power, this being 35.93 per cent of the total power employed in the country for manufacturing purposes. The value of water power, like that of any other commodity, is governed by the law of supply and demand, and depends upon a multitude of circumstances; but inasmuch as water power could not, in any part of the country, be replaced by steam power at a less annual expense than about $20 per net effective horse-power, it will certainly not be an exaggeration to assume that figure as the annual value of a horse-power.* On this basis, the annual value of our utilized water power is about twenty-four million dollars. In its bearing on the industrial economy of the country this figure would be comparable with the annual product of its mines, the annual cut of its forests, or the annual yield of its farms; with the difference, however, that this power is for the most part constant from year to year, and not liable to diminish much in time or to be reduced to nothing, as the output of a mine may be. If it be desired to obtain some idea of the actual, not the annual, value of this power, we may capitalize the above amount at five per cent, giving the sum of say five hundred million dollars. This, however, it must be remembered, represents only the value of the water power already in actual use, and does not include the enormous amount still lying idle, corresponding, in the comparison we are now making, to the untold mineral wealth still lying undiscovered in the bosom of our mountains, or to the agricultural possibilities of our yet uncultivated lands. Unlike these cases, however, some estimate — rough, it is true, but yet not entirely misleading — may be made of the total available water power of the country. A definite amount of water power is generated when some definite quantity of water falls through some definite height. In the perpetual cycle of the elements the mists are raised from the oceans, carried over the land, and precipitated, and of the amount so precipitated a certain proportion flows

* Probably $30 would be nearer the truth.

back to its source, while the rest is immediately disposed of in various ways, being finally again evaporated. The actual amount returned to the sea will depend first of all upon the rainfall, then upon the other climatic conditions, the soil, forests, topography, and a multitude of other circumstances, and may be approximately estimated by comparison with known data; and if in addition the average height above the sea of the ground from which it flows be known, we may easily calculate the total *theoretical* power which it would afford in its course to the sea. Such a calculation of the entire theoretical water power of the country has been made in the Introduction to the 16th volume of the reports of the Tenth Census. The country was divided into a number of sections, in each of which the rainfall, the topography, and the other conditions might be assumed as approximately uniform, and in each of these sections the average elevation of the ground, and the average quantity of water returned annually to the sea, were carefully estimated from the best data obtainable; and from these results the *total theoretical power* was found to be, on the average throughout the year, over two hundred million horse-power, — an amount which it is no doubt safe to say would suffice to operate all the machinery on the globe.

This, however, it must be remembered, is the *theoretical* power, and taken on the average through the year. It includes literally all the power developed by our streams, from their uttermost sources to their very mouths, and it is therefore easy to see that only a small proportion of this enormous total is commercially or even technically available, as may be clearly shown by a single striking example. Thus, the Mississippi River, in its passage from Cairo to the Gulf of Mexico, within which distance no development of power is possible, generates not less than thirteen million horse-power, or over six per cent of the total power just calculated; and when we have deducted from this total all the power technically unavailable, either in the lower courses of the streams,

where they are navigable, or in their upper portions, where they are mere brooks, we shall have left but a very small fraction of the whole. Assuming that we shall have five per cent practically available, and reducing this still farther to two per cent, to allow for the variations in flow in the different seasons, we obtain about four million horse-power as the practically available power during even the driest seasons of the year, and this corresponds to an annual value of eighty million dollars, or, at five per cent, to a capitalized value of sixteen hundred million dollars. This estimate is probably below the truth, but it is of course useless to attempt anything accurate in this direction.

It may not be uninteresting to illustrate these figures by some statements which will render them more easy of comprehension. The utilized water power (1,225,379 horse-power) is considerably greater than the total amount of power (both steam and water) employed in the manufacture of cotton goods, woolen goods, foundry and machine-shop products, iron and steel, and paper combined. If this power were employed in hauling a train of cars on a level track at thirty miles an hour, the train would weigh in the neighborhood of one and a half million tons, or, if made up of the heaviest loaded coal cars, would be about one hundred and sixty-five miles long, while, if made up of Pullman coaches, it would be five hundred miles long.

We may also compare the annual value of our water power with that of our mines, with the following result: —

Annual value of utilized water power at $20 per H. P. . .	$24,000,000
Value of pig iron produced in 1885	64,700,000
Coining value of silver produced in 1885	51,600,000
" " gold " " 1885	31,800,000
Value of coal mined in 1885	159,000,000
Net earnings of all the railroads in the United States in 1885,	266,488,993

It is thus seen that our water power ranks among the more important products — if we may use the expression — of the country.

Let us consider now the geographical distribution of this water power. In Vol. II. of the reports of the Tenth Census may be found some maps showing very clearly the relative amounts of power utilized in different portions of the country. From them it is seen that the principal concentration of power is in New England and in some parts of the middle States. In the southern States there is rarely over three horse-power per square mile, and in the western States very little power at all.

From statistics (see Tables VIII. and IX. in Appendix) taken from the Census Report, it appears that Pennsylvania stands first in the total amount of power used in manufactures, with 15.02 per cent of the total for the United States. New York is second, with 13.31 per cent; Massachusetts third, with 9.08 per cent; and Ohio fourth, with 7.66 per cent of the total. In the amount of water power used New York is first, with 17.90 per cent; Massachusetts second, with 11 29 per cent; Pennsylvania third, with 9 per cent; and Maine fourth, with 6.51 per cent of the total. For steam power we again have Pennsylvania first, with 18.40 per cent; New York second, with 10.74 per cent; Ohio third, with 10.18 per cent; and Massachusetts fourth, with 7.84 per cent of the total.

Further, New York, which stands first in the total amount of water power used, stands seventh in rank as regards water power per square mile, showing but 4.61 horse-power per square mile, while Rhode Island, which stands sixteenth in total water power, stands first in water power per square mile, showing 20.50 horse-power per square mile. The close agreement of the figures for the same State in the last three columns of Table IX. is rather remarkable, the rank in total power, in water power, and in steam power being nearly the same in most cases.

The territory of the United States may be divided into five sections, viz.: the northern Atlantic States, including all those along the Atlantic coast from Maine to Pennsylva-

nia and New Jersey; the southern Atlantic States, including all those along the coast from Delaware, Maryland, and West Virginia, to Georgia and Florida; the northern central, or middle States, including the remaining States north of Kentucky, Arkansas, Indian Territory, and Texas, and east of Montana, Wyoming, Colorado, and New Mexico; the southern central, or middle States, including the States south of the northern boundary of Kentucky, Arkansas, Indian Territory, and Texas; and the western States, including all those west of the eastern boundary of Montana, Wyoming, Colorado, and New Mexico.*

The distribution of the total steam and water power, of the total water power, and of the total steam power used in each of these five divisions is shown in the following table:—†

TABLE I.

Divisions.	Percentage of the total steam and water power.	Percentage of the total water power.	Percentage of the total steam power.
Northern Atlantic	53.05	63.62	47.13
Southern Atlantic	8.63	11.88	6.80
Northern Central	30.16	18.67	36.60
Southern Central	6.17	3.87	7.46
Western	1.99	1.96	2.01

From this we see that 63.62 per cent of all the utilized water power of the country, or nearly two-thirds, is in the northern Atlantic States, while the northern Atlantic and northern central States together include over four-fifths of this total. New England alone reports 34.51 per cent of the total water power, while all the Atlantic States together include 75.50 per cent, or over three-fourths.

*This is the division followed in the report of Mr. Hollerith, from which these tables were taken.

† For the amount of power in the five divisions, see Appendix, Table X.

The relative amounts of steam and water power in these sections of the country are shown in the following table: —

TABLE II.

Divisions.	Water Power.	Steam Power.
	Per cent.	*Per cent.*
United States	35.93	64.07
Northern Atlantic	43.08	56.92
Southern Atlantic	49.48	50.52
Northern Central	22.24	77.76
Southern Central	22.54	77.46
Western	35.33	64.67

In the following table is given the power per square mile in each of these divisions: —

TABLE III.

Divisions.	Area in square miles.	Average power per square mile (steam and water).	Average water power per square mile.	Average steam power per square mile.
		Horse-power.	*Horse-power.*	*Horse-power.*
United States	*2,900,170	1.18	0.42	0.75
Northern Atlantic	162,065	11.16	4.31	6.35
Southern Atlantic	268,620	1.09	0.54	0.55
Northern Central	753,550	1.36	0.30	1.06
Southern Central	*540,385	0.39	0.09	0.30
Western	1,175,550	0.06	0.02	0.04

*Exclusive of Indian and unorganized territory.

The distribution of the water power over the country is easily explained when we come to study the various conditions upon which the existence and the availability of such power depends, and it may be worth our while to glance briefly at some of these factors.

The larger the quantity of water, and the larger the fall, the greater the power developed; therefore, where we have

the largest rivers and the steepest slopes, we shall have the largest powers. But a good water power, whether large or small, should possess certain other qualities; it should be permanent, it should be as nearly unvarying as possible, and it should be easy of utilization. In considering the facilities for water power in any region, therefore, we must first look at its geology, its topography, and the volume of its streams. Where the topography is broken and the slopes are large the streams will fall rapidly; and if the region is occupied by hard metamorphic rocks, over which the rivers descend, the falls will be concentrated at certain definite points where the streams cross the ledges of rock, and will be permanent; and where the volume of the streams is not subject to great fluctuations, but is quite uniform throughout the year, the power will be correspondingly constant. This last factor, the flow of the streams, is so important in the consideration of this question that we may well devote some space to a few facts and details which may perhaps be unfamiliar to those who have not had occasion to investigate problems of this kind. The quantity of water discharged by a river is derived, of course, from the rainfall; the greater the rainfall the greater the discharge of the stream, *other things equal.* But other things are not equal, and the fact is that the absolute amount of rainfall is far from being the most important element in determining the flow. For instance, the way in which that rainfall is distributed through the year exercises a most important influence not only upon the total amount of water discharged by the rivers, but also upon the way in which the flow varies through the year; and cases are not wanting where in two different years the total rainfall upon the same drainage basin was almost precisely the same, and yet in one case the total amount discharged by the stream was double what it was in the other. Consider, for instance, that the rainfall is uniformly distributed throughout the year, the same amount falling in every month. Now, the flow of the streams

will vary from month to month, according to the various conditions which are at work to affect the quantity of the rainfall retained or evaporated. In the summer, when evaporation is most active, the water will fall very low, especially if there are no woods to aid in the retention of the rain as it falls and to cause it to reach the streams gradually, and if there are no large lakes which serve as regulating reservoirs. In the winter also, if the climate is severe, and most of the precipitation is in the form of snow, which remains long upon the ground, the rivers may fall very low; while in the spring the melting snows cause high water, and perhaps destructive freshets. Such is the condition of things in New England; and the Merrimack River, for which we have extended records, is often lowest in the months of January and February, and again in the late summer and autumn. But suppose now that, with the other conditions the same, the rainfall occurs principally in the summer; evidently the summer flow of the streams will be greater, and probably the flow more uniform throughout the year, while at the same time the total amount discharged will be less, since the greatest rainfall occurs just when evaporation is going on most rapidly. Suppose again that the greatest rainfall (or snowfall) occurs in the winter; clearly the summer flow of the streams will be much reduced, and the flow will probably be rendered more irregular.

Not only the amount and distribution of the rainfall through the year, but a great many other factors, affect the discharge of streams, to discuss which would unduly extend the limits of this paper. It will suffice to make the following statement and enumeration of the main elements which are to be considered in examining the water power of any region, and in estimating its value. That water power will in general be the more valuable: —

(*a*) The greater the slope of the streams;

(*b*) The more nearly the fall of the streams is concen-

trated at definite points, the fall at each being neither too great nor too small for economical development;

(*c*) The more permanent the falls are, *i. e.*, the harder the rocks which cause them;

(*d*) The nearer the falls are to navigable waters, and the better the facilities are for transportation by rail;

(*e*) The larger the average flow of the streams;

(*f*) The more uniform the flow of the streams, that is,—to enumerate the principal factors contributing to this result: —

(1) The more favorable the distribution of rainfall through the year;

(2) The less severe the winters;

(3) The more extensive the forests;

(4) The larger the number and area of lakes or artificial reservoirs;

(5) The less steep and rocky the drainage basin (within limits);

(6) The larger the drainage basin.

Glancing over the country, and bearing these facts in mind, we find in New England almost the ideal condition of things: the streams have a large slope, with concentrated falls over the ledges of metamorphic rock which underlie the entire region, the rainfall is favorably distributed, the forests are extensive, the lakes large and numerous, and the facilities for transportation excellent. The streams are navigable for but short distances, deep water is found immediately off the coast, and the lowest falls of the streams are generally at the head of navigation, and but a few miles from the sea.

As we pass westward and southward into the middle States we find a good water-power region drained by the streams flowing into lake Ontario. The rocks underlying this region, however, are comparatively soft and disintegrable, so that the streams have gradually obliterated falls which once existed, until they now flow in gorges which

they have carved out for themselves, and the falls which remain are gradually receding, and in some cases have had to be artificially protected. The rainfall, though perceptibly smaller than in New England, is favorably distributed, being greatest in the summer and autumn, and the streams are well sustained in flow. The greatest power in the country, and probably in the world, occurs in this region,—Niagara, with its total of over six million horse-power from lake to lake, or over five times the total utilized water power of the country. Like the other falls in this vicinity, Niagara is gradually receding as the comparatively soft rocks are worn away by the mighty forces at work.

Throughout the remaining region of the middle States the facilities for water power are not so good. The slopes of the streams are gradual, and abrupt falls are comparatively rare, owing partly to the topography and partly to the softer character of the rocks. The Susquehanna River, for example, though the largest stream on the Atlantic coast, offers not a single large utilized power, and but few sites where power would be economically available, by reason of its great width at the places where falls occur. As we go farther south we again come to a region of harder rocks, though not like those in New England; and the most striking difference, topographically, between the streams of the latter region and those south of the Hudson and Delaware is in the fact that, while in New England the falls are concentrated at distinct points, towards the south the slope of the streams, though not smaller, is nevertheless more uniform, and the falls occur generally in the form of long shoals, which, on account of the length of canal required, and the great width of the rivers at these places, would in general be difficult to develop. There are of course exceptions to this statement, and numerous places may be pointed out in the southern Atlantic States where concentrated falls occur precisely as in New England, but the above is a general statement of the case.

Again, as we proceed southward from the Hudson, along the Atlantic coast, we find between the sea and the lowest falls of the streams — where they take their last plunge from the region of older rocks to that of comparatively recent formations — a gradually widening and gently sloping or almost level region. The eastern boundary of the older rocks is a line passing through Trenton, N. J., Port Deposit, Md., crossing the Potomac a little above Washington, thence passing through Richmond, Weldon, Fayetteville, Columbia, Augusta, Columbus, and Wetumpka. Between this line and the coast the rivers are navigable, though much obstructed by shifting sand-bars and other obstacles, and flow through a low and swampy country, little inhabited, and of no value for power. The water-power region, then, is separated from the coast by from twenty-five to two hundred miles of low and swampy country, and the facilities for transportation by water are correspondingly less than in New England.

Further, when we compare the volume of water carried by the streams in the middle and southern States with that carried by the rivers of New England, we once more find the former at a disadvantage. As we proceed southward, generally speaking, the streams become more variable, the freshets more violent, and the dry-season flow smaller. This result is due to three principal causes: first, the absence of lakes, for south of the Susquehanna river there is not a single lake in the region considered, except one or two near the coast; neither are there any artificial reservoirs, such as are so abundant in New England, and by means of which the low-water flow of many a small stream is doubled or even trebled; secondly, the topography of the country south of the Delaware River, and the structure of the mountain region, is such as would tend to cause an increased variability of flow; and, thirdly, while the rainfall in New England and in parts of the middle States is distributed with a greater quantity in summer and autumn than in winter and

spring, thus giving an increased supply to meet the demands of evaporation during the summer months, the reverse is true in the States south of Pennsylvania and Maryland, thus tending to make the streams more variable.

Few persons, not accustomed to deal with questions of this kind, have an adequate conception of the extent to which the régime of some of our smaller streams has been altered by the agency of man, or of the percentage by which their natural flow in dry seasons has been increased by the construction of artificial storage reservoirs. But our New England States are not wanting in striking illustrations in this direction, one of which is thus referred to by Prof. Porter, in his report upon the water power of the region tributary to Long Island Sound: "The change which may be brought about in the flow of a stream by properly developing the storage capacity of its basin is strikingly seen in the instance of the Pachaug River, a tributary of the Quenebaug, in southeastern Connecticut, draining about sixty square miles. Twenty years ago the Ashland cotton mill, located near the mouth, contained seventy looms, but could only run a portion of the year, and had much trouble from lack of water. The stream was afterwards finely reservoired, however, and now the Ashland mill carries five hundred looms, and has not been stopped more than a day and a half by low water since 1865."

Space will not permit a more extended discussion of the features of these streams. We must cross the Alleghanies and examine the inland basin of the continent. But before doing so, one remark must here be made. It has been stated that the slope of the streams on the Atlantic slope is about the same from Maine to Georgia. This refers to the slope in their water-power portions, that is, from the point where they have attained sufficient volume to become sources of power down to the fall-line before described, or to the head of navigation. Table XI., which gives the slopes of streams in various parts of the country, will show this statement to

be in general true, but an exception must be made in the case of the streams of Maine; and this State is so remarkably situated as regards water power that special attention should be called to it. In the first place, the large streams of Maine generally rise in large lakes, and their tributaries contribute the waters of many others; and this, in conjunction with the favorable distribution of the rainfall, and the extent of the forests,—which here serve a most useful purpose not only in retaining the water and giving it out gradually, but in holding back the snows and not allowing them to be melted rapidly,—operates to render the flow of the streams naturally more uniform, in general, than in any other part of the country. Further, these streams rise at a very considerable elevation above the sea, some of the large lakes of Maine lying at a greater elevation than Lake Itasca, and from them the rivers pour down over ledge after ledge until they meet the sea directly after taking their last great leap, instead of being separated from the ocean by several hundred miles of tortuous and shifting channel, as is the case in some of the southern streams.

A striking comparison, for instance, is that between the Androscoggin River and the Mississippi River. The former has its source at an elevation of about 1500 feet above tide, and descends at an average rate of over eight feet per mile through the 180 miles of its course, giving rise to many fine powers. Its lowest power is but six miles from the sea, at the head of tide and of navigation. The Mississippi has its utmost source at an elevation of about 1580 feet; it descends about 900 feet in a distance of 530 miles to St. Paul; while below that its course measures nearly 2000 miles, so that its slope, within this distance, is only about four inches per mile.

Crossing to the valley of the Mississippi, let us consider first the basin of the Ohio, which includes the greater portion of the area east of the Great Father of Waters. The southern tributaries of the Ohio, as well as its two headwaters, the Alleghany and Monongahela, descend rapidly

from the elevated region where their sources lie, and soon reach the great central plain which stretches with a small and almost uniform slope westward. None of these streams offer great facilities for water power, nor is any appreciable amount utilized upon them. In their upper portions they are very variable in flow, and they drain a wild, inaccessible, and little developed region; while in their lower portions they are navigable for long distances. Owing to the character of the country where they take their rise, the absence of lakes, and the unfavorable distribution of the rainfall, they are liable to sudden rises and severe droughts. What falls they have below their extreme headwaters are mostly in the shape of long shoals, as in their neighbors across the mountains. Thus, the principal fall on the Cumberland is 55 feet in 8 miles, and on the Tennessee 164 feet in 36.5 miles.

The northern tributaries of the Ohio descend with comparatively small slopes from the low divide separating the basin of the Ohio from that of the great lakes. These streams, however, are more favorable for power than those from the south, and are already largely in use. Nevertheless, none of the powers which they afford exceed about 1000 horse-power, for the reason that the fall at command is nowhere very great, and the streams themselves are not large. Like the southern tributaries, these streams flow over a region of comparatively recent geological age as compared with New England, and their beds are of sand or gravel, with no concentrated falls. The rainfall is much less in summer and autumn than in winter and spring, so that these rivers are all very variable, besides having no lakes or reservoirs tributary to them which might serve to regulate their flow. Power is always obtained by raising the water by means of a dam, and it is often difficult to obtain a secure foundation for the structure.

As for the Ohio itself, it is navigable from source to mouth, and offers not a single utilized power, although the power theoretically available at Louisville is very large.

The remarks which have been made regarding the northern tributaries of the Ohio will apply in general to the smaller eastern tributaries of the Mississippi, as well as to the streams flowing into Lake Erie, and those draining the peninsula of Michigan. None of them offer large powers. Towards the headwaters of the Mississippi, however, in the Northwest, the condition of things is essentially different. There the slope of the surface is quite rapid; either southward or toward the great lakes, the country is rough and broken, and is underlaid with hard metamorphic rocks. The streams fall rapidly, and their slopes are not uniform, but concentrated. The rainfall is small, varying from twenty-five to thirty-five inches, but is favorably distributed; and the country is dotted with innumerable lakes, some of them of considerable size, which serve to regulate most beneficially the flow of the streams. This region is really the only distinctly water-power district west of the Appalachian system, and aside from the severity of the climate, which is an objection in more ways than one, it will bear favorable comparison with even New England. A large amount of power is still unutilized in this region, which, however, with the rapid growth of the Northwest, will no doubt be soon called into requisition.

The western tributaries of the Mississippi, or more especially of the Missouri, belong to a class of streams entirely different from any that have yet been considered. Stretching from the base of the Rocky Mountains eastward to the Missouri, the prairies present what appears to be a gently rolling surface lying almost at a uniform general elevation, or with no decided inclination in any direction; really, however, they have a very considerable and quite uniform slope of from two to six or eight feet per mile toward the east. They are almost entirely without woods, but covered largely by a rich growth of grass; and although in some places sandstone and limestone appear at the surface, by far the greater portion of the area is underlaid by a thick deposit


Map of the United States
Showing location of
large concentrated water powers

Excess of steam over water power
Excess of water over steam power
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
ATLANTIC OCEAN
GULF OF MEXICO
CUBA
CHOCTAW NATION
CHICKASAW NATION

of drift or loess. The streams flow in shallow basins, with low divides on either side, their slopes are almost absolutely uniform, and their beds sand or mud. It is a mistake which is often made to suppose that the prairie streams are as a rule sluggish, for their average slope is often greater than that of the streams of New England. But the character of the bed is such as to offer in many cases an insecure foundation, and very many of the dams in this region are built of brush, and are not over ten feet high. The uniform slope of the streams renders it possible to obtain a power in almost any region where the bed and banks will permit of the necessary structures, but the powers obtained are nowhere large. The flow of these streams is not only very small indeed in proportion to the area drained, on account of the small rainfall, the great evaporation, and the porous character of the soil, but it is very variable. No lakes or storage reservoirs are present to regulate the flow, and although the rainfall in spring and summer is much greater than in autumn and winter, most of these streams all but run dry at certain times of the year, even some of the larger ones being converted into a series of shallow pools. Thus, while in New England there are probably few streams which do not discharge annually from thirty to fifty per cent of the rainfall of their basins, Humphreys and Abbot give a ratio of but fifteen per cent for the entire Missouri River. A reference to Table XII. will further show the extreme variability in the flow of these streams.

In the mountainous regions of the Rocky Mountains the slope of the streams is of course large, and their beds often rock, but the main use of their waters here is for irrigation, for the wants of which there is even now not a sufficient supply, and it seems very unlikely that there will ever be any considerable utilization of water power in this region.

The tributaries of the Mississippi from eastern Iowa have a much larger slope than the true prairie streams, and rock exposures often occur along their courses, giving rise to

rapids, and offering favorable sites for power. Considerable power is utilized here, and much more is still available, although none of the powers are individually large.

The water power of the streams west of the Rocky Mountains has never been officially examined and reported upon, and little can here be stated regarding it. In the Rocky Mountain region the streams are topographically generally unfitted for the development of power, and in the Great Basin region what water there is will probably be needed for irrigation. On the Pacific coast the slope of the streams is very large, but the exceeding variability of the rainfall, and its very small amount in many portions of the coast, render the streams very variable in flow. Only those which head far up in the Sierras, where they are fed by the melting snows, are sustained in the summer time; the others run dry. And with the increasing practice of irrigation in California it is probable that manufacturing by water power will never be extensively carried on there.

Tables XI. and XII. in the Appendix will serve to illustrate the points thus far discussed; Table XI. gives the slope of the working portions of streams in different parts of the country; and Table XII. gives some statistics regarding the flow of streams, showing very clearly the great differences between the prairie streams and those of the Atlantic slope.

Finally, before leaving this portion of our subject, we may consider the larger developed and undeveloped powers of the country. Map No. 1 shows by circles the large powers of the country, both developed and undeveloped, the areas of the circles being roughly proportional to the amount of power used or available. It will be noticed that the large powers are all on the Atlantic slope (including the basin of Lake Ontario), and in the Northwest. These are the water-power regions of the country. The map shows clearly the greater concentration of fall of the streams in New England, the powers being large and at definite points, while the Chattahoochie River, for instance, is one succession of long

shoals with a very large aggregate amount of power, but, except in one or two instances, no very abrupt descent at any one place. It must be remembered that this map is not intended to show only powers technically or commercially available, but to illustrate the distribution over the country of undeveloped as well as developed powers. Thus, the enormous power near the mouth of the Susquehanna River, comprised in one long fall covering a distance of nine miles, is not in any way utilized, and probably will not be, on account of technical and commercial disadvantages and difficulties. The largest power in the country, that at Niagara Falls, is not shown on the map, for obvious reasons.

The following statistics will further illustrate the distribution of the large powers of the country: —

Table XIII. (in Appendix) shows that in New England there are five developed powers where over 10,000 horse-power* are used during working hours, and a total of twelve available powers of this magnitude, provided the water could be stored at night so as to be used during the day; while there are thirteen powers of over 2000 horse-power in use, and a total of thirty-eight available. The middle States, including Virginia, possess fifteen powers of large size, some of which, however, would be very difficult to develop; while the southern Atlantic States are very rich in available powers, whose utilization, however, would in a great many cases be too expensive to render the power commercially of value. The Northwest has some large powers, and most of them could easily be developed. It must not be forgotten that this table shows nothing of the comparative commercial availability of these powers, and although the southern Atlantic States offer a greater number of powers of over 2000 horse-power, yet there are not by any means as many of these available as there are in New England. It is to be noticed that west of the Alleghanies, except in the Northwest, there is not a

* This refers to theoretical horse-power during twelve hours, in dry seasons, supposing that the water could be stored, and not wasted, during the other twelve hours.

single really large developed power, and none economically available.

Those whose attention has never been particularly called to the subject of the development of power, and whose acquaintance with the subject is confined to such small powers as may be developed by damming some unimportant stream to run a grist mill or a small factory, may have a very imperfect conception of the magnitude of the engineering works involved in the development of a power of such magnitude as to be the foundation of a manufacturing city. Such cases, as has been seen, are not uncommon in New England. At Lawrence, Mass., the Merrimack River is crossed by a masonry dam 900 feet long and 32 feet high, built in 1845–6 at a cost of $250,000. From this dam two canals extend down stream, one on each bank, and between these and the river are located the mills, occupying the entire river front, on the north side at least, for a distance of over a mile. The cost of the canal on the north side, 5330 feet long and 100 feet wide at the upper end, was $250,000; and of that on the south side, 2000 feet long and 60 feet wide, $150,000. The enormous power here generated by the fall of about 28 feet is utilized by 22 mills of various kinds, but principally in the manufacture of cotton and woolen goods.

At Holyoke, Mass., the Connecticut river is crossed by a timber dam 1017 feet long and 35 feet high. From it the water flows into the upper canal. There are three canals, at three different levels, and the water passes from canal to canal, through mill after mill, until it finally reaches the river again. The power here, aggregating over 10,000 horse-power night and day, is utilized by 27 paper mills and 26 other mills of various kinds.

It is interesting to compare the conditions at Lawrence, Kan., with those at Lawrence, Mass. At the former place the fall is one third of that at Lawrence, Mass., but the drainage area is over twelve times as great; yet the power

available at Lawrence, Mass., is three or four times that at Lawrence, Kan., even supposing that the water at the latter place could be stored during the night.

Let us now consider the water power of the country in comparison with its steam power. We have already seen that the water power constitutes about thirty-six per cent of the total power in use, and the Tables have shown further comparisons between the water power and the steam power. Map No. 2, taken from Vol. II. of the Census Reports, shows the regions where there is an excess of water power over steam power, and, with a different shading, those where there is an excess of steam power over water power. It will be observed that New England and most of New York show an excess of water power; the same is true in the Northwest, and along the Alleghanies in the southern States. In practically all other parts of the country, excepting a few patches along some good streams, there is an excess of steam power. Of course, in regions particularly favorable for water power, such as the Atlantic slope and the Northwest, we should naturally expect to find a large amount of utilized water power. In the other regions of the country, where the water powers are small and unreliable, steam of course is always preferred. In comparing these two sources of power, no general statement can be made as to which is preferable. It all depends upon circumstances. Neither can any general statement regarding the comparative cost of the two be made. It all depends on circumstances again. To say that water power is cheaper than steam power, or the reverse, is about like saying that coal is more expensive than wood as fuel. In comparing the two, however, some important points of difference are to be borne in mind, the most obvious of which is that while steam power is available wherever fuel can be obtained,—is mobile and independent of any particular location, — water power is limited to definite localities. Mills using steam power may therefore be located in just the position most favorable to eco-

nomic production, and to quick disposal of the finished product. Leaving out of consideration for the moment the actual annual expense in dollars and cents of utilizing power, represented by the interest on the first cost of the motors and appurtenances, and the annual running expenses, water power will stand on nearly the same ground as steam power when it is located at points equally favorable from a commercial point of view; and in the case of industries which need large quantities of water for other purposes than power, and which naturally seek a location on some stream, water power will have somewhat the advantage. In fact, many prefer water power to steam, even at the same price, on account of the greater cleanliness and less inconvenience in its use, the smaller area required, its greater safety, etc. On the other hand, steam is often preferred as offering a steady and reliable power, independent of the fluctuating state of a river, and not subject to interruptions from droughts or freshets. But, leaving this out of the question, there are clearly always these three factors to consider, — the actual cost of the power, the commercial facilities of the site, and the requirements of the manufacture. The last two, though of equal importance with the first, cannot be expressed in figures, and therefore no general statement regarding the relative value of the two sources of power can possibly be made. The cost of steam power, however, can never be reduced below a certain limit, representing, as has been said, the interest on first cost of plant, etc., and the cost of fuel, attendance, and supplies. Supposing that fuel costs as low as $4 per ton, and taking the case of a mill using a large amount of power, say over 500 horse-power, the cost, under the most favorable circumstances, will not be less than about $20 per net effective horse-power per annum. The cost of water power, as well, cannot be reduced below a certain limit, representing the interest on first cost, and the annual expense of operation, but this limit is much lower than the above, being perhaps $10 per net effective horse-power per annum, for a case

not the most favorable which could be supposed. If now a very easily available water power exists at a point commercially favorable, and if it is utilized in a kind of manufacture which would of necessity be located on some stream of like nature, the cost of the water power will be very much less than that of steam power. Of course, there are water powers, not very far from Boston, to develop which would be so expensive that the cost of the water power would be double or treble what steam power would cost on the same spot. There are others which would cost scarcely anything to develop, but which are located in inaccessible regions, and are therefore not commercially favorable, unless some manufacture exists which must needs be located in just that spot, in which case water power would be much cheaper for it than steam. Convenient facilities for transportation constitute, in general, the most important factor affecting the commercial value of a water power, and many such powers which are technically all that could be desired, are rendered almost valueless by the lack of this element, unless the raw material is produced and the finished product disposed of in the immediate vicinity. So there are water powers and water powers, and to make a comparison between the cost of water power and that of steam power at any one place, and to imagine that the result has any general value, seems about like comparing the cost of coal and wood as fuel in Boston, with the idea that the results will apply the world over, and for every kind of manufacture.

These considerations may be illustrated by means of Table IV. which gives the distribution of power among the more important industries, and the proportion of water power and steam power used by each.

The table shows that of the selected industries the largest proportion of water power, 70.70 per cent, is found in the case of paper mills. These mills require large quantities of clear water for purposes of their manufacture, and would naturally be located on some stream, so that the larger pro-

TABLE IV.

Industries.	1870. Total water power.	1870. Per cent of total water power of the United States.	1870. Per cent of total power in industry. Water power.	1870. Per cent of total power in industry. Steam power.	1880. Total water power.	1880. Per cent of total water power of the United States.	1880. Per cent of total power in industry. Water power.	1880. Per cent of total power in industry. Steam power.	Average total power (steam and water) used per establishment.	Total number of establishments.
	H. P.				*H. P.*					
Agricultural implements	10,209	0.90	39.14	60.86	12.645	1.03	28.27	71.73	34.92	1,281
Boots and shoes (factory)	167	0.01	5.44	94.56	410	0.03	3.54	96.46	15.62	741
Cotton goods *	99,073	8.76	67.84	32.16	148,754	12.14	53.99	46.01	288.18	956
Flouring and grist-mill products	407,950	36.09	70.74	29.26	469,987	38.35	60.94	39.06	31.79	24,258
Foundry and machine-shop products	......	....	......	......	15,364	1.25	15.34	84.66	23.79	4,209
Iron and steel	14,631	1.29	9.72	90.28	16,506	1.35	4.16	95.84	508.64	781
Lumber, sawed	326,728	28.90	50.93	49.07	278,686	22.74	33.91	66.09	32.01	25,680
Paper	41,644	3.68	78.25	21.75	87,611	7.15	70.70	29.30	179.06	692
Sashes, doors, and blinds	7,758	0.69	......	......	6,505	0.53	17.16	82.84	33.48	1,132
Silk and silk goods	789	0.07	41.29	58.71	1,562	0.13	17.73	82.27	44.72	197
Woolen goods	52,906	4.68	62.17	37.83	53,610	4.38	50.33	49.67	53.68	1,984
Worsted goods	4,634	0.41	57.81	42.19	6,302	0.51	38.34	61.66	216.28	76

* Including both specific and special cotton mills.

portion of water power is easily explained. Again, of the total power used in flour and grist mills, about 61 per cent is water power. This finds its explanation in the fact that the majority of these mills are small, and for local use only; the raw material and the finished product are respectively produced and consumed in the immediate neighborhood, and convenience of transportation enters little into the question; so that water power, on account of its intrinsic cheapness, is preferred. In the manufacture of cotton and woolen goods one-half the total power is water power, and in the case of worsted goods the proportion of water power is still above the average for the entire country. On the other hand, the proportion of water power employed in the manufacture of boots and shoes, and of iron and steel, is very insignificant. In the former case this is explained by the very small amount of power used per establishment, the small use of water for purposes of manufacture, and the almost forced location in certain places; and in the case of iron and steel, questions of location and ease of transportation explain the small proportion of water power. In fact, if we compare the proportion of water power in the manufacture of iron and steel with that in foundry and machine-shop products,— where it is used in smaller and more local establishments,— we find a much larger proportion in the latter case.

The investigations of the Tenth Census give very extended results as to the price charged for water power by companies in various parts of the country, and it is interesting here to make some comparisons of the actual cost of water and steam power, leaving out of consideration general questions of location and of particular conditions of manufacture, which, as we have said, cannot be expressed in figures. We shall then be enabled to judge whether, as a fact, water power, *as actually used*, is more expensive or less expensive than steam power. It will first be necessary to make an estimate of the cost of steam power. Now, this is of course dependent upon a number of considerations, such

as whether steam has to be used under any circumstances as a means of heating, or in other ways (in which case the exhaust steam can be used for these purposes, and a portion of the cost of the plant as well as of the cost of maintenance should not be charged to the power account); also upon the cost of fuel, which is itself dependent upon the location and the means of transportation. As a basis for our calculations, we will take the following data:* we suppose a large amount of power required, say 1000 horse-power, we assume the coal to cost $4.30 per long ton, and we assume that the consumption of coal is 2 or 2.5 pounds per indicated horse-power per hour. Large compound engines, under favorable circumstances, have been found to give one horse-power to from 1½ to 1¾ pounds of coal, but it may safely be said that the ordinary steam engines found in mills are not giving a figure as low as this, any more than that the ordinary turbine wheels in use give an efficiency of 85 per cent because certain forms of wheel have given that percentage under favorable tests. The larger the amount of power used, and the more constant the service, the smaller will be the cost per horse-power. Large engines can be run with a much smaller consumption of fuel, per horse-power, than small ones, and the total cost of attendance increases in a much smaller ratio than the amount of power used. While large compound condensing engines may be run at an expenditure of 1½ pounds of coal per indicated horse-power per hour, small non-condensing engines frequently use 4 or 5 pounds, or even more. And it may be remarked here that, while steam power costs much more in small than in large quantities, the reverse is frequently the case with water power, so that to compare the cost of large quantities of power is — so far as concerns the ordinary conditions through-

* The principal data for this estimate are taken from a valuable paper by Mr. Charles T. Main, Superintendent of the Lower Pacific Mills, in Lawrence, on the Relative Cost of Steam and Water Power. The estimates have here been made in precisely the manner indicated by Mr. Main, using, however, in some cases, figures which appear to the writer to be more in accordance with the conditions generally existing.

out the country — much more unfavorable to water power than would be the comparison of the cost of small quantities.

Taking the frictional resistance of engine and gearing at 12 per cent, we then have the consumption of coal as 2.27 or 2.84 pounds of coal per net effective horse-power per hour, which, at 10¼ hours a day equals 23.27 or 29 11 pounds per day. The cost of attendance and supplies will be about $0.018 per horse-power per day, or $5.56 per horse-power per annum. Let us now distinguish three cases, as follows: —

Case I. — No steam required for any purpose except for running the engine. (2 pounds of coal per indicated horse-power per hour.)

Case II.—Ordinary cotton mill. Steam used for running engine, for heating mills from Nov. 1 to April 1, or five months, and steam used throughout the entire year for slashers. (2.5 pounds of coal per indicated horse-power per hour.)

Case III. — Woolen or worsted mill, with dye house. Steam used all the year for dyeing whole production, and for wool washing and dressing. Steam used for five months for warming buildings. (2.5 pounds of coal per indicated horse-power per hour.)

Omitting the details of the calculations, we shall then have the results given in the following table: —

TABLE V.

Showing cost of steam power under various conditions, per net effective horse-power, per annum, for large powers.

	Case I.	Case II.	Case III
	Coal at $4.30 per ton.	Coal at $4.30 per ton.	Coal at $4.30 per ton.
Attendance and Supplies	$5.56	$5.56	$5.56
Coal*	13.81	12.31	6.80
Taxation, Interest and Depreciation, Repairs, Insurance, etc.	11.82	9.86	8.61
Total	$31.19	$27.73	$20.97

* For price or consumption of coal different from those assumed, this figure will be varied in proportion.

This calculation is made for a power of 1000 horse-power. For smaller powers the cost per horse-power would be considerably greater.

The first cost of a large water-power *plant*, where the water is delivered in the canal by a water-power company, will be approximately $55 per net effective horse-power for large powers of from 800 to 1000 horse-power. This gives, for taxation, repairs, depreciation, interest, and insurance, an annual cost of about $6.70 per net effective horse-power. Attendance and supplies will amount to about $0.77. But allowing for the fact that the capacity of the plant, in order to furnish the necessary quantity of power at all ordinary stages of the water, must be greater than necessary to furnish the same amount when the head is greatest, we shall assume the total annual cost of the plant per net effective horse-power at $9. This, I think, will be found sufficient in the majority of actual cases. The total annual cost of the water power will be this amount added to what is paid for the water used. It remains to give the cost of the water furnished by the various companies selling water in this country, and for that purpose the following table has been compiled: —

TABLE VI. Cost of water power.*

Place, and conditions.	Cost of water per N. E. H. P. per annum.	Total cost of power per N. E. H. P. per annum.
Lawrence, Mass., for power originally granted...	$15.00	$24.00
" " " surplus up to 20%.........	20.61	29.61
" " " " 20 to 50%.........	41.22	50.22
" " " " above 50%........	20.61	29.61
" " for permanent leases at present..	20.00	29.00
Lowell, Mass., for original leases................	15.00	24.00
" " " surplus up to 40%............	25.75	34.75
" " " " " 40-50%.........	51.50	60.50
" " " " " 50-60%.........	103.00	112.00
" " " " during "backwater"..	5.15	14.15
Manchester, N. H., for surplus power...........	25.75	34.75
Saco and Biddeford, Me., for surplus power.....	15.45	24.45
Lewiston, Me., ordinary leases..................	2.50 to 12.50	11.50 to 21.50
Windsor Locks, Conn. (according to fall).........	18.00 to 27.00	27.00 to 36.00
Holyoke, Mass..................................	12.87	21.87
Turner's Falls, Mass............................	7.50	16.50
Bellows Falls, Vt..............................	7.50	16.50
Unionville, Conn...............................	16.20	25.20
Occum, Conn....................................	20.00	29.00
Barrett's Junction, Mass........................	9.00	18.00
Birmingham, Conn., "permanent water.".......	27.00	36.00
" " 1st surplus..................	16.00	25.00
" " 2nd "	11.00	20.00
Ansonia, Conn., "permanent water."...........	28.50	37.50
" " surplus.........................	12.00 to 24.00	21.00 to 33.00
Oswego, N. Y., 1st class........................	19.00	28.00
" " 2nd "	13.50 to 16.10	22.50 to 25.10
" " surplus	9.35 to 12.50	18.35 to 21.50
" " (2nd privilege) 1st class..........	9.30 to 11.30	18.30 to 20.30
" " " 2nd and 3rd class...	4.70 to 5.65	13.70 to 14.65
Cohoes, N. Y....................................	21.00	30.00
Rochester, N. Y. (at one privilege)...............	25.00	34.00
Lockport, N. Y..................................	12.00 to 15.90	21.00 to 24.90
Niagara Falls, N. Y. (1.)........................	10.00	19.00
" " " (2.).......................	7.00	16.00
Passaic, N. J...................................	47.50	56.50
Paterson, N. J..................................	51.00	60.00
Trenton, N. J...................................	53.50 to 71.00	62.50 to 80.00
Fredericksburg, Va..............................	5.00 to 15.00	14.00 to 24.00
Manchester, Va..................................	42.00 to 60.00	51.00 to 69.00
Augusta, Ga.....................................	5.50	14.50
Hamilton, Ohio..................................	27.30 to 62.90	36.30 to 71.90
Middletown, Ohio................................	41.00	50.00
Franklin, Ohio..................................	42.00	51.00
Dayton View, Ohio...............................	52.00	61.00
Dayton, Ohio....................................	43.00	52.00
" " (from M. and E. Canal)............	35.30 to 40.00	44.30 to 49.00
Appleton, Wis. (with land), 500-1000 H. P........	1.00 to 2.00	10.00 to 11.00
" " " 100-300 H. P.........	3.00 to 4.00	12.00 to 13.00
" " " 50 H. P..............	2.00 to 3.00	11.00 to 12.00
Kaukauna, Wis. " 100-300 H. P..........	2.00 to 5.00	11.00 to 14.00
Lawrence, Kansas................................	20.00	29.00

*Efficiency of wheel assumed at 80 per cent. This is high, as an average, for actual wheels, but for a different per cent the cost can easily be calculated, being inversely as the efficiency.

From this table it will be seen that the cost of water power varies from $11 or $12 per net effective horse-power in the Northwest to from $60 to $80 in New Jersey. That water power is used in New Jersey at these rates, and that it is sometimes used in New England when it costs more than steam, seems to argue that its other advantages — such as greater cleanliness, less annoyance, and less area required — have a very considerable money value. The price of coal in Paterson, N. J., is less than in Lowell, Mass., yet all the available water power at the former place is eagerly utilized at a price of about $60 per horse-power, or, let us say, at double what steam power would cost.

The conclusion to which I therefore think we must be led in this matter is this: that if it is simply a question of power, without reference to anything else, water power is cheaper, far cheaper. If a man wishes simply to develop 100 or 1000 horse-power, regardless of anything else, he could certainly do it more cheaply by going to some water power than by putting up a steam plant. But when other factors are taken into consideration, as they always must be, circumstances differ, though there is no doubt that at favorably located sites water power is produced more cheaply than steam power would be. It is not to be forgotten that the figures above given refer to power sold by water-power companies whose principal object is not to furnish power as cheaply as it can be furnished but to make money for themselves, and who consequently charge as high a price as they can get for their goods. Water power competes with steam power on the same basis on which Wamsutta cottons compete with New York Mills cottons in our markets. In places, like Lowell and Lawrence, where steam and water power are both easily obtained, we should not expect to find any very great difference in the price of the two. Remembering that, other things equal, water power is considered to have some advantages over steam power, if its cost is a little higher than that of steam, it does not follow that it cannot

be produced even more cheaply than steam, and still yield a fair profit to its owner; while, if its cost is less than that of steam, it is almost conclusive proof that it is produced more cheaply.

Finally, in closing this paper, it may be well to glance for a moment at the changes in the utilized power of the country which have taken place since 1870.

The following table shows the total steam and water power in use in 1870 and 1880:—

TABLE VII.

	WATER POWER.			STEAM POWER.			
	Number of water wheels.	Horse power.	Horse power per wheel.	Number of steam engines.	Horse power.	Horse power per steam engine.	Total steam and water power (h.p).
1880....	55,404	1,225,379	22.12	56,483	2,185,458	38.69	3,410,837
1870....	51,018	1,130,431	22.16	40,191	1,215,711	30.25	2,346,142
Percentage of increase.	8.60	8.40	....	40.54	79.77	....	45.38

From this we see that the total amount of power used in manufactures, both steam and water, increased 1,064,695 horse-power during the decade. Of this total increase, 94,948 horse-power, or 8.92 per cent, was due to the increase in the amount of water power used, while 969,747 horse-power, or 91.08 per cent, was due to the increase in the amount of steam power used. The average power of the water wheels slightly diminished, probably on account of the introduction of various forms of small hydraulic motors for light work.

It is evident that the steam power increased within the decade very much more rapidly than the water power. In 1870 the proportion of water power in the entire country was 48.18 per cent, while in 1880 it was 35.93 per cent. The proportion of water power decreased in every state and ter-

ritory excepting Arizona, Dakota, Idaho, Iowa, Kansas, Louisiana, Montana, and Nebraska. According to the census tables, there has in every State and territory been an increase in the actual amount of steam power used, while there has been a decrease in the actual amount of water power used in California, the District of Columbia, Indiana, Louisiana, Maryland, Michigan, Nevada, Ohio, Pennsylvania, Tennessee, Virginia, Washington, and West Virginia. Still, since these figures represent the power used in manufactures alone, the total power in use may nevertheless have been increased in some of these States. The actual as well as the proportional decrease may possibly be explained in part by the rapid cutting down of our forests, and the consequent abandoning, in some regions, of saw mills which existed in 1870, but principally by the fact that, in these days of sharp competition, location and commercial facilities of every kind are of far more importance than a few dollars more or less expended for power; while the advantages of a fixed and steady power afforded by a steam engine over the uncertain and fluctuating power furnished by a natural stream are becoming more and more recognized. No doubt the proportion of steam power will continue to increase, yet we shall see new water powers developed and eagerly used as soon as increased transportation facilities render them able commercially to compete with more central localities.

Finally, I must observe that the maps and tables accompanying this paper, having been based upon the information given in the Census Reports already published, are incomplete as far as concerns the main stream of the Mississippi, and its tributaries above the Ohio, and also the gulf streams of Mississippi and Louisiana, the reports covering them not having yet appeared.

APPENDIX.

Percentage of the total amount of steam and water power, of the total amount of water power, and of the total amount of steam power for each State and Territory; also the rank of each State in regard to amount of power used: —

States and Territories.	Rank in total power.	Percentage of the total steam and water power.	Rank in water power.	Percentage of the total water power.	Rank in steam power.	Percentage of the total steam power.
Alabama	27	0.81	23	0.96	25	0.72
Arizona	47	0.02	44	0.01	47	0.02
Arkansas	31	0.46	35	0.17	28	0.63
California	25	0.97	30	0.40	18	1.28
Colorado	37	0.17	36	0.15	36	0.18
Connecticut	8	3.47	6	4.99	11	2.61
Dakota	41	0.07	43	0.07	40	0.07
Delaware	32	0.45	31	0.39	33	0.49
Dist. of Columbia	40	0.09	42	0.07	39	0.10
Florida	36	0.21	40	0.08	34	0.28
Georgia	22	1.50	12	2.45	21	0.97
Idaho	46	0.05	38	0.09	44	0.02
Illinois	6	4.23	21	1.42	6	5.80
Indiana	7	3.86	17	1.78	7	5.03
Iowa	18	1.59	18	1.66	14	1.55
Kansas	29	0.62	28	0.62	29	0.62
Kentucky	17	1.61	26	0.74	12	2.10
Louisiana	34	0.33	46	0.01	31	0.52
Maine	10	2.95	4	6.51	22	0.95
Maryland	21	1.50	20	1.47	16	1.52
Massachusetts	3	9.08	2	11.29	4	7.84
Michigan	5	4.83	11	2.81	5	5.96
Minnesota	19	1.58	14	2.34	20	1.15
Mississippi	30	0.54	33	0.28	27	0.69

States and Territories.	Rank in total power.	Percentage of the total steam and water power.	Rank in water power.	Percentage of the total water power.	Rank in steam power.	Percentage of the total steam power.
Missouri	13	2.37	27	0.67	9	3.32
Montana	43	0.04	39	0.08	45	0.02
Nebraska	35	0.25	29	0.45	38	0.14
Nevada	46	0.02	45	0.01	43	0.03
New Hampshire	12	2.57	5	5.64	24	0.85
New Jersey	11	2.93	15	2.21	8	3.33
New Mexico	44	0.04	41	0.08	46	0.02
New York	2	13.31	1	17.90	2	10.74
North Carolina	23	1.32	13	2.45	26	0.69
Ohio	4	7.66	9	3.15	3	10.18
Oregon	33	0.40	25	0.76	35	0.20
Pennsylvania	1	15.02	3	9.00	1	18.40
Rhode Island	14	1.86	16	1.81	13	1.80
South Carolina	28	0.76	22	1.13	30	0.55
Tennessee	20	1.52	19	1.51	15	1.53
Texas	26	0.90	34	0.20	19	1.28
Utah	38	0.14	32	0.29	41	0.05
Vermont	15	1.86	7	4.26	32	0.51
Virginia	16	1.68	10	3.06	23	0.90
Washington	39	0.13	37	0.10	37	0.15
West Virginia	24	1.11	24	0.77	17	1.30
Wisconsin	9	3.11	8	3.70	10	2.78
Wyoming	45	0.02	47	*	42	0.03

* Less than 0.004 of 1 per cent.

TABLE IX.

The total power, the water power, and the steam power per square mile in each State and Territory, with the rank of each in regard to amount of total power, water power, and steam power per square mile.

States and Territories.	Area.	Total steam and water power per square mile.	Water power per square mile.	Steam power per square mile.	Rank in total power per square mile.	Rank in water power per square mile.	Rank in steam power per square mile.
	Sq. miles.	*H. P.*	*H. P.*	*H. P.*			
Alabama	51,540	0.54	0.23	0.31	28	26	28
Arizona	112,920	0.01	*	*	43	44	45
Arkansas	53,045	0.30	0.04	0.26	30	33	30
California	155,980	0.21	0.03	0.18	33	35	32
Colorado	103,645	0.06	0.02	0.04	39	36	38
Connecticut	4,845	24.40	12.63	11.77	4	4	4
Dakota	147,700	0.02	0.01	0.01	41	39	40
Delaware	1,960	7.87	2.44	5.43	9	11	8
District of Columbia	60	52.38	14.67	37.72	2	3	2
Florida	54,240	0.13	0.02	0.11	35	37	34
Georgia	58,980	0.87	0.51	0.36	25	19	25
Idaho	84,290	0.02	0.01	0.01	42	40	41
Illinois	56,000	2.58	0.31	2.27	16	25	12
Indiana	35,910	3.67	0.61	3.06	13	17	11
Iowa	58,475	0.98	0.39	0.61	23	23	22
Kansas	81,700	0.26	0.09	0.16	31	30	33
Kentucky	40,000	1.37	0.23	1.15	20	27	16
Louisiana	45,420	0.25	*	0.25	32	45	31
Maine	29,895	3.36	2.67	0.69	14	9	21
Maryland	9,860	5.20	1.83	3.37	12	12	10
Massachusetts	8,040	38.53	17.21	21.32	3	2	3
Michigan	57,430	2.87	0.60	2.27	15	18	13
Minnesota	79,205	0.68	0.36	0.32	27	24	26
Mississippi	46,340	0.40	0.07	0.32	29	31	27
Missouri	68,735	1.17	0.12	1.06	22	28	19
Montana	145,310	0.01	0.01	*	44	41	46
Nebraska	76,185	0.11	0.07	0.04	37	32	39
Nevada	109,740	0.01	*	0.01	45	46	42
New Hampshire	9,005	9.74	7.68	2.06	7	5	14
New Jersey	7,455	13.39	3.63	9.76	5	8	5
New Mexico	122,460	0.01	0.01	*	46	42	47
New York	47,620	9.54	4.61	4.93	8	7	9
North Carolina	48,580	0.93	0.62	0.31	24	16	29
Ohio	40,760	6.41	0.95	5.46	11	13	7
Oregon	94,560	0.14	0.10	0.05	34	29	36
Pennsylvania	44,985	11.39	2.45	8.96	6	10	6
Rhode Island	1,085	58.59	20.50	38.10	1	1	1
South Carolina	30,170	0.86	0.46	0.40	26	20	24
Tennessee	41,750	1.24	0.44	0.80	21	21	20
Texas	262,290	0.12	0.01	0.11	36	43	35
Utah	82,190	0.06	0.04	0.01	40	34	43
Vermont	9,135	6.93	5.72	1.21	10	6	15
Virginia	40,125	1.42	0.93	0.49	19	14	23
Washington	66,880	0.07	0.02	0.05	38	38	37
West Virginia	24,645	1.54	0.38	1.15	18	22	17
Wisconsin	54,450	1.95	0.83	1.12	17	15	18
Wyoming	97,575	0.01	*	0.01	47	47	44

*Less than 0.005 horse power per square mile.

TABLE X.

Distribution of power in different sections of the United States.

Divisions.	Total steam and water power.	Water power.	Steam power.
	Horse-Power.	*Horse-Power.*	*Horse-Power.*
United States	3,410,837	1,225,379	2,185,458
Northern Atlantic	1,809,515	779,595	1,029,920
Southern Atlantic	294,186	145,568	148,618
Northern Central	1,028,680	228,770	799,910
Southern Central	210,520	47,444	163,076
Western	67,936	24,002	43,934

TABLE XI.

Slope of streams flowing into the Atlantic and the Eastern Gulf.

Stream.	From—	To—	Distance.	Fall.	Slope per mile.
			Miles.	*Feet.*	*Feet.*
Saint Croix	Chiputneticook lake	Tide	55	383	7.0
Penobscot	Source	"	173	1,509	8.7
Kennebec	Moosehead lake	"	112	1,023	9.1
Androscoggin	Rangeley lake	"	180	1,511	8.4
Saco	Conway, New Hampshire	"	73	412	5.6
Merrimack	Lake Winnipiseogee	"	124	500	4.0
Connecticut	West Stewartstown	"	294	1,035	3.5
Connecticut	Source	"	325	2,038	6.3
Hudson	North River village	"	102.5	1,039	10.1
Mohawk	Rome, New York	Mouth	115	418	3.6
Delaware	Deposit, New York	Tide	212	984	4.6
Susquehanna	Source	"	422	1,193	2.8
Potomac	Cumberland, Maryland	"	185	610	3.3
James	Clifton Forge, Virginia	"	225	1,014	4.5
Roanoke	Danbury ford (on the Dan river)	Head of navigation	208	651	3.1
Cape Fear	Haw river (on Haw river)	Foot of Smiley's Falls	110	605	5.5
Yadkin	Patterson, North Carolina	Fall-line	241	1,145	4.8
Catawba	Old Fort, North Carolina	"	318	1,430	4.5
Congaree	Green river (on Broad river)	"	143	629	4.4
Oconee	Near Lula, Georgia	"	145	984	6.8
Chattahoochee	Near Gainesville, Georgia	"	215	751	3.5

TABLE XI.—*Continued.* Slope of the southern tributaries of the Ohio.

Stream.	From —	To —	Distance.	Fall.	Slope per mile.	Remarks.
			Miles.	*Feet.*	*Feet.*	
Cumberland	Nashville, Tenn	Mouth.	192	79	0.41	Navigable during six months for steamers of 300 tons.
Green	Bowling Green, Tennessee	"	175	60	0.34	Navigable by locks and dams.
Kentucky	Mouth of Middle Fork	"	258	228	0.88	Navigable by locks and dams for 95 miles above mouth.
Licking	West Liberty, Tennessee	"	231	310	1.34	
Great Kanawha		"	89	86	0.96	
Little Kanawha	Bulltown, West Virginia	"	131	200	1.53	
Monongahela	Mouth of West Fork	"	123	132	1.07	Navigable by locks and dams for 102 miles.
Alleghany	Olean, New York	"	255	725	2.84	

TABLE XI.—*Continued.* Slope of the northern tributaries of the Ohio.

Stream.	From —	To —	Distance.	Fall.	Slope per mile.	Remarks.
			Miles.	*Feet.*	*Feet.*	
Wabash	Mouth of Little river	Mouth.	370	385	1.0	Navigable for some distance.
Great Miami	Dayton	"	77	298	3.9	Extensively used for power.
" "	Piqua	"	108	422	3.9	
Sciota	Columbus	"	110	225	2.04	Not navigable.
"	Green Camp	"	152	433	2.8	
"	Extreme source	"	210	933	4.4	
Muskingum	Dresden	"	91	130	1.4	Navigable by locks and dams.
"	Mouth of Walhonding river.	"	151	367	2.4	

TABLE XI.—*Continued.* Slope of some tributaries of the Missouri, and of some streams in the Northwest.

Stream.	Tributary to what.	From what State.	From —	To —	Distance.	Fall.	Slope per mile.
					Miles.	*Feet.*	*Feet.*
Missouri river	Mississippi river	Missouri	Fort Benton, Mont.	Mouth	2,644	2,464	0.93
Dakota river	Missouri river	Dakota	N. P. R. R. crossing	C. and N. W. R. R. crossing.	252	157	0.62
Big Sioux river	"	"	Watertown, Dakota	Mouth	221	639	2.89
Little Sioux river	"	Iowa	Cherokee	Near mouth	79	101	1.28
Boyer river	"	"	Near Denison, Iowa	Mouth	59	148	2.51
Nishnabatona river	"	Missouri	Near Atlantic, Iowa	"	120	230	1.92
Nodaway river	"	"	Near Villisca, Iowa	Near mouth	91	160	1.76
Platte river of Missouri	"	"	Near Conception, Mo.	"	119	321	2.70
Grand river	"	"	Near Gentryville, Mo.	Mouth	128	181	1.41
Chariton river	"	"	Chariton, Iowa	Near Keytesville, Missouri.	186	403	2.17
Niobrara river	"	Nebraska	Near source	Mouth	355	3,829	10.78
Platte river	"	"	North Platte, Neb.	"	304	1,890	6.22
Elkhorn river	Platte river	"	Near O'Neill, Neb.	Near mouth	201	858	4.27
Loup river	"	"	Head of Middle Loup	"	257	1,796	7.00
North Platte river	"	"	North Park, Colorado	North Platte	514	4,836	9.41
South Platte river	"	"	Denver, Colorado	Mouth	285	2,454	8.61
Kansas river	Missouri river	Kansas	Junction of forks	Near mouth	184	330	1.79
Big Blue river	Kansas river	"	Seward, Nebraska	"	153	384	2.51
Republican river	"	"	West line of Nebraska	Mouth	423	2,530	5.98
Smoky Hill river	"	"	Wallace, Nebraska	"	395	2,275	5.76
Osage river	Missouri river	Missouri	Ottawa, Kansas	"	417	358	0.86
Gasconnade river	"	"	Indian Ford, Mo.	"	78	108	1.38
Milwaukee river	Lake Michigan	Wisconsin	Headwaters	"	66	500	7.58
Sheboygan river	"	"	"	"	45	360	8.00
Manitowoc river	"	"	"	"	42	350	8.33
Lower Fox river	"	"	Lake Winnebago	"	37	165	4.40
Menominee river	"	"	Sources	"	160	975	6.09
Red river of the North	Hudson's bay	Minnesota and Dakota	Otter Tail lake	Breckenridge, Minnesota	34	368	10.82
Red river of the North	"	" "	Breckenridge, Minn.	National boundary	394	165	0.42

TABLE XI.—*Continued.* Slope of the streams of eastern Iowa.

Stream.	From—	To—	Distance.	Fall.	Slope per mile.
			Miles.	*Feet.*	*Feet.*
Maquoketa river	Manchester, Iowa	Mouth	87	333	3.83
Wapsipinicon river	Independence, Iowa	"	135	328	2.43
Iowa river	Near Iowa Falls	"	215	485	2.26
Cedar river	Cedar Falls, Iowa	Mouth of Iowa river	176	323	1.84
Skunk river	Southeast part Hamilton County, Iowa	Mouth	203	551	2.71
Des Moines river	Windham, Minnesota	"	411	853	2.08

TABLE XI.—*Continued.* Slope of some of the lower tributaries of the Mississippi.

River.	Tributary to what.	From—	To—	Distance.	Fall.	Fall per mile.
				Miles.	*Feet.*	*Feet.*
Meramec river	Mississippi river	Head spring	Mouth	172.5	390.5	2.26
Saint Francis	"	Headwaters	"	438.0	1006.0	2.30
"	"	Eastern boundary Butler Co., Mo	"	308.0	170.0	0.55
Arkansas	"	Source	Pueblo, Col	155.0	5287.0	34.11
"	"	Pueblo, Col	Fort Gibson, Ind. Ter	812.0	4208.0	5.18
"	"	Fort Gibson, Ind. Ter	Mouth	642.0	398.0	0.62
Red	"	Source	Missouri, Kansas, and Texas R. R. crossing	504.0	1919.0	5.19
"	"	Missouri, Kansas, and Texas R. R. crossing	Mouth	1025.0	517.0	0.50
White	Arkansas river	Forsyth, Mo	"	590.0	458.0	0.77
"	"	Head of West Fork	Forsyth, Mo	257.0	1333.0	5.18

TABLE XII. Table of the flow of streams.

Stream.	Place.	Drainage Area.	Rainfall.					Extremes of flow.			Min. flow cub. ft. per sec. p. sq. m.	Ordinary low water flow.	
			Spr.	Sum.	Aut.	Win.	Yr.	Max. cub. ft. per sec.	Min. cub. ft. per sec.	Ratio		Cub. ft. per sec.	Cub. ft. per sec. per sq. m.
		Sq. miles.	In.	In.	In.	In.	In.						
Merrimack river	Lawrence, Mass.	4,599	10	11	13	9	43	96,000	1,400	69	0.30	2,800	0.60
Concord river	Lowell, Mass.	361	11	11	12	10	44	4,449	60	74	0.17	126	0.35
Sudbury river	Framingham, Mass.	78	11	11	12	10	44	3,228	2.8	1,153	0.036	12.5	0.16
Connecticut river	Hanover, N. H.	3,316	10	12	12	10	44	......	1,006	....	0.303	1,210	0.365
Oswego river	Oswego, N. Y.	5,013	8	10	9½	7	34½	4,100	1,153	36	0.23	1,500	0.30
Passaic river	Paterson, N. J.	813	12	14	12	10	48	17,913	195	92	0.24	....	.....
Delaware river	Lambertville, N. J.	6,820	11	13	11	9	44	350,000	2,000	175	0.29	....	.....
Schuylkill river	Philadelphia, Pa.	1,912	12	14	10	9	45	......	310	....	0.16	....	.....
Potomac river	Great Falls, Md.	11,476	12	13	9	8	42	175,000	1,063	165	0.093	....	.....
"	Cumberland, Md.	920	10	12	9	8	39	17,900	25	716	0.022	....	.....
Ohio river	Pittsburgh, Pa.	18,732	10	12	9	10	41	......	2,271	....	0.12	....	.....
Kanawha river	Charleston Pool, W. Va.	8,900	12	13	9	10	44	118,291	1,100	108	0.123	....	.....
Scioto river	Columbus, O.	1,686	10	11½	8	8½	38	......	25	....	0.015	....	.....
Lower Fox	Foot of Lake Winnebago	6,046	9	12	9	5	35	......	2,320	....	0.38	2,500	0.413
Mississippi river	Grand Rapids, Minn.	3,636	7	12	6	3	28	......	......	....	.....	969+	0.27+
"	Hannibal, Mo.	137,460	7½	12	8	4	31½	......	......	....	.....	30,000	0.218
Minnesota river	Mouth	17,230	6½	11	5½	3	26	......	1,155	....	0.067	....	.....
Illinois river	"	29,013	11½	11	9	8	39½	......	1,600	....	0.055	1,750	0.06
Des Moines river	"	14,578	8½	13½	9	4	35	......	......	....	.....	....	0.09
Missouri river	St. Charles, Mo.	527,000	6±	6±	4±	3±	19±	430,000	15,000	29	0.028	....	.....
Kansas river	Topeka, Kan.	56,354	8±	7±	6±	3±	24±	......	2,000	....	0.035	....	0.043
Arkansas river	Arkansas City, Kan.	44,500	3	9	3	2	17	......	675	....	0.015	....	.....
"	Mouth	160,000	..	..	..	..	..	......	......	....	.....	3,000	0.019

TABLE XIII.

Developed and Undeveloped Powers in the United States in 1880.

H.P. refers to theoretical horse-power during twelve hours, in dry seasons, supposing that the water could be stored, and not wasted, during the other twelve hours.

States.	Number of developed powers, *utilizing* in 1880.			Number of undeveloped powers, with an available power of			Total number of powers, with an available power of		
	Over 10,000 H.P.	Over 5,000 H.P.	Over 2,000 H.P.	Over 10,000 H.P.	Over 5,000 H.P.	Over 2,000 H.P.	Over 10,000 H.P.	Over 5,000 H.P.	Over 2 000 H.P.
Massachusetts	3	4	4	0	0	0	4	4	4
New Hampshire	1	1	3	1	1	3	2	5	9
Vermont	0	1	1	0	0	0	0	1	1
Between New Hampshire and Vermont	0	0	0	0	2	2	0	2	2
Maine	1	1	4	2	6	9	5	15	19
Connecticut	0	0	1	0	1	2	1	2	3
New York	0	3	8	2	4	7	9	12	26
New Jersey, or between New Jersey and Pennsylvania	0	0	1	0	2	2	1	4	5
Pennsylvania	0	0	0	2	2	2	2	2	2
Between Maryland and Virginia	0	0	0	2	4	4	2	4	4
Virginia	0	0	1	—	—	—	—	—	—
West Virginia	0	0	0	1	1	1	1	1	1
North Carolina	0	0	0	3	4	6	3	4	6
South Carolina	0	0	0	4	9	13	4	9	13
Georgia	0	0	2	0	2	31	2	4	33
Between South Carolina and Georgia	0	0	0	2	3	4	2	3	4
Alabama	0	0	0	1	1	26	2	2	27
Kentucky	0	0	0	1	1	1	1	1	1
Minnesota	1	1	1	3	3	3	5	5	5
Wisconsin	0	0	1	5	8	12	7	11	15
Kansas	0	0	0	0	0	0	0	0	1
New England	5	7	13	3	10	16	12	29	38
Middle States	0	3	10	7	13	16	15	23	38
Southern Atlantic States	0	0	2	10	19	80	13	22	83
Northwest	1	1	2	8	11	15	12	16	20